UNIVERSITY OF PENNSYLVANIA

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EDWIN FORBES TAIT

A THESIS

IN PSYCHOLOGY

PRESENTED TO THE FACULTY OF THE GRADUATE SCHOOL IN
PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

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A RECIPROCAL REFLEX SYSTEM IN THE ACCOMMODATION-CONVERGENCE RELATIONSHIPS

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For many years there has been considerable speculation among workers in psychological and physiological optics regarding the relationship between the functions of accommodation and convergence in preserving clear single binocular vision. Helmholtz advanced the theory that these functions normally go hand in hand and that they are, in their mutual relationship, the manifestations of a built-up association not belonging to the class of congenital involuntary concomitant movements.[1]

Interest in the problem was lacking for many years and it remained without experimental investigation until the general development of visual psychology and physiology brought it to the attention of Sheard,[2] who presented, in 1917, the problem in a concise and systematic manner for the first time. Sheard recognized the importance of the psychological aspects of the problem and began his work by attempting to reduce the judgmental errors inherent in the older purely subjective methods by the development of a more objective system for the determination of the accommodation and convergence values. The methods then developed are the basis of those used in the present investigation. So far, however, it has been impossible to utilize wholly objective methods and thus the present investigation assumes a considerably more psychological than physiological character.

A fairly complete citation of the meager literature up to 1920 will be found in the paper by Sheard.[3] As a result of the work reviewed, Sheard comes to the conclusion that 70% of persons possessing low refractive errors, but with otherwise normal eyes, show from 2–7 prism diopters of accommodative exophoria at a fixation-distance of one-third meter, and he further concludes that the optimum condition is one where there is from 4–5 prism diopters at that distance.

When binocular vision at near is required, as in reading, it is evident that the visual axes must converge toward the point of fixation. The amount of accommodative exophoria represents the amount of that convergence which is supplied by the fusion faculty in the interest of single binocular vision, but as this usually represents only about one-fourth of the whole, the major part of the convergence

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[1] H. von Helmholtz, *Handbuch der Physiologischen Optik,* 3rd. ed., 3, 1910, 48, 51.

[2] Charles Sheard, *Dynamic Ocular Tests,* 1917.

[3] Sheard, On accommodative exophoria, *Amer. J. Physiol. Opt.,* 1, 1920, 234.

present in normal cases must therefore be due to the convergence innervation stimulated by the use of the accommodation and designated in this paper as accommodative-convergence.

Weymouth, Brust, and Gobar,[4] in 1925, support Sheard's conclusions and add somewhat to the historical background.

Ames and Gliddon,[5] using an adaptation of the Pereles and Hess apparatus, as described by Howe,[6] have shown that the actual accommodation used in reading rarely corresponds exactly to the fixation-distance, due to the ability of the visual perceptive centers to resolve retinal images even when they are formed by multiple diffusion circles. For a fixation-distance of one-third meter, however, they found the accommodative lack to be only from about 0.08 to 0.25 diopters. Values of this order, important as they are in a survey of accommodative phenomena, may safely be ignored in this investigation as they are considerably less than the expected experimental error. For all practical purposes, therefore, the amount of accommodation required for a fixation-distance of one-third meter may be considered as three diopters.

All the preceding investigations, however, are concerned either with the characteristics of accommodation or with the effect produced upon the convergence by the exercise of accommodation or accommodative effort. The possibility of a comparable or reciprocal reflex wherein accommodation may be the result of convergence or convergent effort has not heretofore been considered.

The object of this investigation is to establish the presence or absence of reflex accommodation due to a convergence stimulus, and if it apparently is present, to ascertain its values and characteristics as far as possible. It is obvious that the only approach is from a combined objective-subjective standpoint, obtaining, independently, the convergence value subjectively and the accommodative value objectively.

If, by suitable methods, the accommodation resulting from the convergent impulse, if any such be obtained, be measured and compared with the amount of convergence present when the subject is accommodating, with the fusion faculty non-operative, any positive correlation between the two would support Helmholtz's theory of a true association relationship, built up as the result of simultaneous use of accommodation and convergence in the early years of life.

No objective procedure would be sufficiently valid in the measurement of convergence due to the fact that the point upon the cornea through which the visual line passes and upon which an objective determination must depend cannot at present be determined accurately. The amount of

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[4] F. W. Weymouth, P. R. Brust, and F. H. Gobar, Ocular muscle balance at the reading distance and certain related factors, *ibid.*, 6, 1925, 184-205.

[5] A. Ames and G. Gliddon, Ocular measurements, *Presessional Vol. Sec. Ophth., Amer. Med. Assn.*, 1928, 11-47.

[6] Lucien Howe, *The Muscles of the Eyes,* 1907, 329-330.

accommodation, however, can best be determined objectively as skiametry affords the most accurate means with which to calculate the total refraction at any given distance.

Skiametry, as used for many years by refractionists, is carried on by the use of a skiascope or retinoscope, which, in its simplest form, is an adaptation of the ophthalmoscope and consists essentially of a small round mirror with a sight hole in its center. When the light from a suitable source of illumination is reflected into the eye of the subject, the observer, peering through the aperture in the mirror, observes the illumination in the subject's pupil and notes that if he tilts the mirror slightly the pupillary illumination apparently shifts in a direction either coinciding with, or opposite to, the movement of the incident light. Meanwhile the attention of the subject is directed to a suitable fixation-object, which may be at any distance, and lenses are placed in front of his eyes so that the reflex movements become extremely rapid and eventually are completely neutralized. This point of neutralization occurs when the subject's retina, which is here acting as a secondary source of illumination, is conjugate with the principal nodal point of the observer's eye. Knowing the distance between the skiascope and the subject's cornea, the lense value in diopters can easily be calculated.

Most modern skiascopes have a self-contained illuminating mechanism, but are used in precisely the same manner as the simpler type. Dynamic skiametry is skiametry carried on while the subject is converging to, and fixing upon, a near object. This modified system, first described by Cross,[7] and developed further by Sheard,[8] and considered by the latter as the most accurate existent method of investigating the negative relative accommodation, presented little difficulty in application.

With an emmetropic, or normal eyed, individual or one made so by the proper corrective glasses, there must be approximately 3 diopters of accommodation exerted in order to see small print distinctly at a distance of 1/3 m. If fixation is constant but the accommodation varied by the introduction of convex lenses, there will be some relaxation of accommodation in most cases, but rarely will the individual, if under the presbyopic age, accept the full 3 diopters of convex lens power which would relax the accommodation completely. Usually there will be, as shown by clinical experience, a greater or lesser amount of accommodation retained, apparently due to the presence of convergence for, when the latter is relieved by the application of prisms base-in, the full convex value of 3 diopters is usually promptly accepted.

In an attempt to determine the accommodative status subjectively, however, acceptable judgments as to the point of beginning blur are difficult to obtain, probably due to the ability of the visual centers to resolve blurred retinal images. In the experience of the author, objective determinations of the refractive, and therefore accommodative, status may be carried on by the aid of dynamic skiametry with a possibility of error not exceeding ½ diopter. In addition this procedure permits the use of sufficient initial convex lense power to promote ciliary muscle relaxation to the point of the convergent-accommodative innervation. The differ-

[7] A. J. Cross, *Dynamic Skiametry in Theory and Practise,* 1911.
[8] Charles Sheard, *Dynamic Skiametry,* 1920.

ence between the spherical lense value found by dynamic skiametry and that accepted subjectively by the subject would, when subtracted from the 3 diopters necessary for focussing at 1/3 m., be equal to the amount of accommodation stimulated by the convergence to, and fixation upon, the near-point fixation-object.

It is possible to measure the amount of accommodative convergence used by an individual under given conditions of near-point fixation by dissociating the fusion faculty by the application of a prism with the base down in front of one eye and then bringing into vertical coincidence by measured prisms the diplopic images produced by such a procedure. The base-in prism value necessary for coincidence represents the accommodative exophoria provided that the distance ocular muscle imbalance, if existent, has been previously corrected. The total convergence of the visual axes from parallelism to fixation at 1/3 m. may then be calculated in accordance with the formula developed by Weymouth, Brust, and Gobar.[9] The accommodative convergence may then be calculated by subtracting the accommodative exophoria from the total convergence as found by the above formula. This method of calculation, developed by the author, avoids the exceedingly laborious graphic method suggested by Maddox and quoted and amplified by Sheard.[10]

Subjects. The results of a quantitative study of 500 individuals, by methods developed in the study of the foregoing considerations, are here presented. All of the *Ss* were between the ages of 10–40 yr.—not less than 10 yr. in order to insure reasonable accuracy in the subjective determinations, and not over 40 yr. due to the desirability of avoiding the lessened accommodative amplitudes which usually become apparent after that age. All had, also, single binocular vision, visual acuity of 6/6 with the proper correcting lenses, and, in cases where visual defects were present, wore the proper correcting lenses. An arbitrary division into 4 age-groups was made in order to afford, as far as possible, a basis of comparison between relatively older and relatively younger groups. The majority of the *Ss* were college and high school students, but, as will be seen from the tabulations, a sufficient number of older persons was included in order that the results might not represent the conditions prevailing among the younger individuals only. The *Ss* were selected from among a considerable number of persons who had reported to the author for routine examinations for visual efficiency after having previously been examined for visual defects.

All the *Ss* were entirely uninformed as far as the problem was concerned, considering the procedure simply as part of the routine procedure for the determination of visual efficiency. The results have been considered collectively so that there was no need to identify the *Ss* in any way except by numbering them successively from 1 to 500.

In selecting *Ss*, care was taken to eliminate from consideration the few cases in which there was a manifest condition of eye-strain due to uncorrected ametropia, muscular anomalies such as convergent squint or hyperphoria, and where the astigmatic correction was not consistent or varied during the investigative procedure.

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[9] F. W. Weymouth, P. R. Brust, and F. H. Gobar, Ocular muscle balance at the reading distance and certain related factors. *Amer. J. Physiol. Opt.*, 6, 1925, 189.
[10] Sheard, *Dynamic Ocular Tests*, 1917, 60.

Apparatus. The apparatus consisted of a standard DeZeng phorometer, equipped with a near point target; an ordinary ophthalmic trial case; a test cabinet for visual acuity judgments and fixation; a self-luminous dynamic skiascope, and a 10-cm. rule graduated in mm. The phorometer was supported by a suitable floorstand and contained, before each eye, 3 cells for the reception of the trial case lenses and a rotary prism calibrated to read from 0–30 prism diopters. The rotary prism is attached in such a manner as to make possible the placing of the prism base-apex line in any given direction. In addition there is a white near-point card, measuring 13 cm. square and with a 4 mm. black E printed in its center, held upon a rod at a distance of 1/3 m.

The ophthalmic trial case used for the phorometer cells is composed of convex and concave cylindrical lenses, and is so arranged that any given lense power may be obtained by one or a combination of two or more lenses. It is calibrated in the familiar lense dioptric system.

The test cabinet used was the 20th Century Cabinet produced, like all the other items of apparatus, by the American Optical Company. Used at a distance of 6 m., for which it is calibrated, its fixation-letters are calculated to subtend a 5′ angle at their designated distances. The increasing size of the letters gives successively 6/6, 6/7.5, 6/10, 6/12, 6/15, 6/20, 6/30, and 6/60, in terms of visual acuity. The numerator represents the fixation-distance while the denominator expresses the smallest letters seen clearly at that distance. Thus 6/12 visual acuity means that *S* cannot see clearly letters smaller than the 12 m. group at a distance of 6 m.

The last of the series, the 6/60 object, consists of the one letter, E, and was the stimulus used for fixation in determining the presence and amount of esophoria or exophoria for distance. The smaller letters were used for the judgment of visual acuity with 6/6 considered as the optimum amount.

For the skiametric procedure, the skiascope used was the Tait dynamic instrument, developed by the author, and described fully in a previous paper.[11]

Procedure. The procedure was identical with every *S* regardless of age. The name and age of *S* were first noted and then the inter-pupillary distance was measured by the parallax method with the millimeter rule. This distance, ascertained when each eye was fixing straight ahead, is obviously equal to the distance between the centers of rotation of the two eyes which is the basis for the total convergence calculation. Dynamic skiametry was the next procedure. With sufficient convex lense power before each eye to make *S* artificially myopic for the fixation distance, his attention was directed to the skiascope target on the side opposite to that of the eye upon which *E* was working. The fixation-target to which *S*'s attention was directed, was previously illuminated by the chart illuminating device which is part of the instrument. *S* was then given the following directions:

Look constantly at the illuminated target on the instrument even if you do not see it clearly. Tell me if at any time you see two targets.

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[11] E. F. Tait, A quantitative system of dynamic skiametry, *Amer. J. Optom.*, 6, 1929, 669-693.

By tilting the skiascope and observing the fundus reflex, the movement of the margin of the reflex was then noted and if it was in the direction opposite to the movement of the light upon the face, the convex lense value was reduced until the movement was extremely rapid, showing that the conjugate focus to *S*'s retina was approximately coincident with the position of the principal nodal point of *E*'s eye. If the initial movement coincided with the facial illumination, higher convex lenses were applied until the movement was in the opposite direction. As long as the movement of the reflex was rather slow, the lense values were successively reduced in each eye, shifting *S*'s attention to the right and the left targets successively, but as soon as the movement became rather rapid the attention of *S* was directed to the illuminated chart to his left and the right eye was then carried to the point of extremely rapid movement of the reflex. Then the skiascope illumination was shifted to the chart on the other side and the left eye corrected in the same way and to the same extent. Lack of fixation by both eyes was readily noticeable by reason of the rapid changes in the reflex or by *S*'s report of diplopia. The values thus found were recorded as the dynamic skiametric results. Shifts in the rate and type of the reflex movements were readily observable with lense differences of 0.25 diopter so that this figure would represent the maximum experimental error.

A careful subjective judgment procedure, with fixation at 6 m. and utilizing the same principle of supplying excess convex lense power and then reducing, was the next operation. One eye at a time was occluded and the highest plus lense with which 6/6 or better vision was attainable was noted as the subjective finding. In the vast majority of *S*s the astigmatism, if present, required for correction the same cylindrical value in the subjective procedure as in the dynamic, and only such cases are here presented, as those having variable cylindrical values introduced a consideration foreign to the purpose of this paper, that of compensatory lenticular astigmatism.

For the determination of the esophoria or exophoria at 6 m., a six-prism diopter prism, with the subjective lense correction in place, was inserted base down in front of the right eye and *S*'s attention directed to the 6/60 letter E in the test cabinet. *S* was then questioned as follows.

You now see two Es off in the distance. Is the lower E directly under the upper one, or is it to the right or to the left?

The rotary prism was then swung into place in front of the left eye with its base-apex line in the proper direction, and *S* given the following instructions.

Tell me just when the lower E is directly under the upper one.

If the rotary prism, when vertical coincidence was secured, is base out, esophoria was present; if base in, exophoria, and this and the amount were noted.

The same procedure was then followed with fixation at 1/3 m. on the near-point fixation-target and the esophoria or exophoria for near determined. During this process sufficient time, usually 1–2 min., was permitted for the lower E to settle into position as it usually oscillated somewhat while the prism value was slowly changing.

Discussion of method. It may readily be seen that the dynamic determination corrected not only *S*'s refractive error but that between the lenses and his accommodation the added positive refractive power for the near-point fixation was supplied. If the distance correction as found by the subjective method is then com-

pared with the dynamic skiametric findings, the amount of accommodation used during the dynamic procedure may be calculated readily by subtracting from 3 diopters the difference between the two.

That the stimulus for this accommodation is not due to the lack of a clear retinal image with less accommodation is apparent when the details of the dynamic method are considered. Sufficient convex lense power to relieve accommodation totally was present during the early phases of the operation, but was not utilized by the eye. It can be shown by inhibition with base in prisms that this residual accommodation is due to the convergent stimulus and that it, when present, is an indication of the efficiency of the convergence-accommodation reflex.

In the study of convergence it has been necessary to utilize the classification of ocular muscle anomalies, suggested by Stevens,[12] wherein the terms esophoria and exophoria serve to classify the possibilities in horizontal heterophoria. Esophoria is considered as indicating a tendency, while the fusion faculty is functioning to neutralize it and prevent actual movement, of the visual axes of the two eyes to converge with respect to each other. Exophoria, on the other hand, indicates a tendency toward divergence of the visual axes under the same conditions. Both esophoria and exophoria are necessarily relative to the distance of fixation and to the influence of accommodation. In the determination of either of these conditions the first requisite is to suspend the action of the fusion faculty and thus destroy its power to innervate the extra ocular muscles in the interest of single binocular vision. This procedure, accomplished by the use of one of the many dissociation methods, in the present instance by the use of a six-prism diopter prism base down in front of the right eye, permits the visual axis of each eye to assume a definite position determined by the extent and distribution of the reciprocal tonic innervation to the extra ocular muscles; provided that the fixation is at distance and any refractive defects are corrected by proper glasses. Where accommodation is in use, as in near fixation, more or less convergence effect stimulated by the accommodative action is usually added to the basic tonic innervational distribution, thus effecting a difference in the angular relations of the visual axes from those obtaining at distance. The effect of this accommodation can be measured without difficulty by comparing the results of the distance convergence determination with those of the near. By reason of the slight judgment error and the lack of accurate calibration of the rotary prisms to less than one prism diopter, there was an inherent maximum error of that amount in measuring esophoria or exophoria. Weymouth, Brust, and Gobar's table was therefore used only to the nearest full prism diopter value when calculating the total convergence from parallelism to the visual axes to fixation at 1/3 m. from the corneae.[13] Following are the total convergence values for pupillary distances of from 55–70 mm.

Pupillary Distance (in mm.)	Total Convergence (in prism diopters)
55–58	16
59–61	17
62–65	18
66–70	19

[12] G. T. Stevens, *Motor Apparatus of the Eyes,* 1906, 215.
[13] Weymouth, Brust, and Gobar, *op. cit.,* 190.

Convergent Accommodation (In diopters)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
2.00										1		2	1			1						
1.75									1		1	4	2	1		2						
1.50				1			2	2	1	2	4	9	20	13	17	11	7	6	7	1	2	2
1.25			1		1		1	1	3	8	13	9	11	4	11	10	9	3	2	1		
1.00				1	1	2	5	12	12	5	18	10	9	5	6	4	5					
.75				1	1	8	16	8	11	10	7	7	2	3		1		2		1		1
.50	1	1	3	1	8	7	4	6	10	3	4	3	4		1		1					
.25	1	2	2	3	5	3	2	4	2		2			1								
0	11	6	2	3	2		1	1														

Accommodative Convergence
(In prism diopters)

Fig. 1. Distribution of 500 Ss, Ages 10–40 Yr.

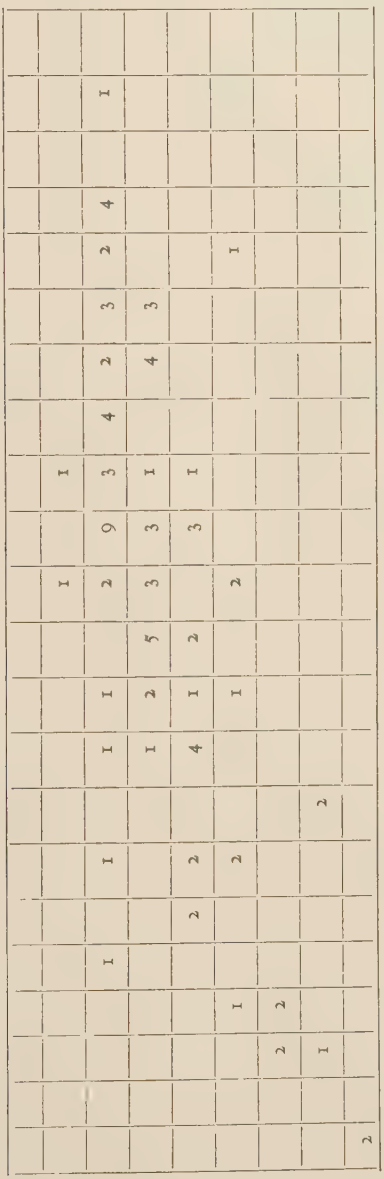

Fig. 2. Distribution of 89 Ss, Ages 10–17 Yr.

Fig. 3. Distribution of 190 Ss, Ages 18–25 Yr.

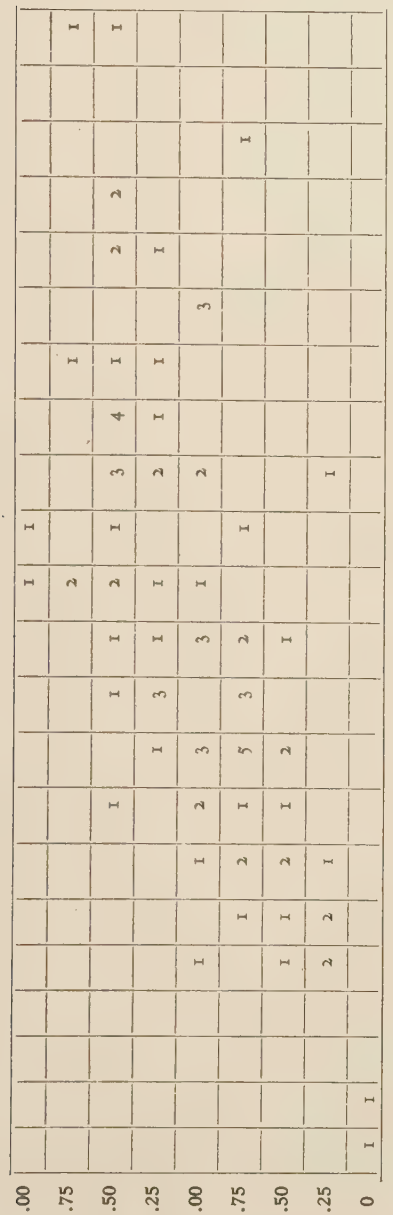

Fig. 4. Distribution of 84 Ss, Ages 26–30 Yr.

Convergent Accommodation (In diopters)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
2.00										1												
1.75									1		1		1			1					1	
1.50								1			2	3	7	4	1	3	2	2	1			
1.25							1		1	1	3		4		4	2	2	1		1		
1.00				1			1	3	2	1	8	6	1	1	3	2						
.75						1	1	4	1	3	2	3		2		1		1				
.50				1	1	2	3	1	3	2	3	1	2		1		1					
.25		1		3	1	1				1	1											
0	3	2	1	2																		

Accommodative Convergence
(In prism diopters)

Fig. 5. Distribution of 137 Ss, Ages 31–40 Yr.

For purposes of calculation esophoria was considered as a plus quantity and exophoria as minus. The accommodative-convergence was then calculated by substituting in the following formulae:

$$(1)\ N_e - D_e = P_e$$
$$(2)\ C_t + P_e = C_a$$

Where:

N_e = Near point esophoria or exophoria,
D_e = Distance esophoria or exophoria,
P_e = Physiological exophoria or esophoria,
C_t = Total convergence from parallelism to one-third meter, and
C_a = Accommodative convergence.

Results

The distribution of the 500 cases with respect to their accommodative convergence and convergent accommodation value will be found in Fig. 1. In this whole series the greatest amount of convergent accommodation encountered was 2 diopters and the greatest amount of accommodative convergence was 21 prism diopters with 5 *Ss* each. On the other hand, there were 11 *Ss* with neither accommodative convergence nor convergent accommodation. The other *Ss* were distributed with noticeable regularity between these two extremes. A superficial inspection of the table will show that convergent accommodation is not only present in most cases but that there is a very positive correlation between it and the accommodative convergence. The actual coefficient of correlation, by the Product-Moment Method,[14] is $+0.73 \pm .014$.

The distributions of the 4 age-groups will be found in Figs. 2-5. Fig. 2 gives the results and scatter of the pre-college group, ages 10-17 yr.; Fig. 3, of the college group, ages 18-25 yr.; Fig. 4, of the group between the college and the pre-presbyopes, ages 26-30 yr.; and Fig. 5, of the pre-presbyopic group with diminished amplitudes of accommodation, ages 31-40 yr.

It will be noted that age has apparently no modifying effect upon the presence of either accommodative convergence or convergent accommodation as the general character of the distribution is similar in all 4 age-groups, the atypical as well as the typical cases being represented in each. In considering the atypical aspects of the distribution, it should be noted that there are relatively few cases in which there is accommodative convergence without convergent accommodation or convergent accommodation without accommodative convergence. A noteworthy characteristic of the convergent accommodation distribution is that, while there are 107 *Ss*

[14] H. E. Garrett, *Statistics in Psychology and Education*, 1926, 163-168.

in the 1.50 diopter group, there are only 15 *Ss* in the 1.75 diopter group, 6 in the 2.00 diopter group, and none higher. Between 0 and 1.50 diopters, however, is a steadily increasing number for every 0.25 diopter increase. This would give a badly skewed curve if plotted according to the amount of convergent accommodation.

The curve for the accommodative convergence would, on the other hand, show a very definite regularity if allowance were made for the inequalities introduced by the apparent predilection of the observer for even numbers in the choice of values made necessary by the lack of fractional sub-divisions on the rotary prisms.

Discussion. In view of the fairly high positive correlation obtained between the accommodative convergence and the convergent accommodation determinations, it is apparent that Helmholtz's view is supported and amplified in so far as that is possible with the relatively limited number of *Ss* studied. If we consider that the laws of association, as deduced from learning experiments, are valid in subliminal conscious processes as well as in the conscious (and there is no good reason for not doing so) the results of this investigation may be taken as indicating that there is usually a reciprocal relationship existing between accommodation and convergence, the source and type of the stimulus depending upon whether the accommodation or the convergence is the dominant factor. In this investigation, the author first made the convergence dominant by securing binocular fixation at a near-point and eliminating accommodation as far as possible by supplying convex lense power equal to the focal length of the fixation-distance. Under these conditions some accommodation did relax and was measured by the amount of plus lense value which had to be deducted from the initial plus excess.

Dominancy was then transferred to the accommodation by permitting the eyes to use a normal amount of accommodation and at the same time eliminating the influence of the fusion faculty, thus freeing convergence. The convergence existing under such conditions must be that which is stimulated by the presence of accommodation.

Binocular fixation and accommodation for a near point, however, if the values obtained in this experiment may be taken as representative, involve more of both accommodation and convergence than the usual amounts supplied when either is the stimulus and the other the effect. Inasmuch as accommodation is the primary requirement for clear vision, it is probable that the usual dominancy is that of the accommodation, which would give more or less accommodative convergence depending upon the efficiency of the reflex. This is the more likely in that there is a very effective mechanism in the fusional convergence innervation for supplying any de-

ficiencies in accommodative convergence. The convergent accommodative reflex probably would not, therefore, be effective under ordinary conditions, but would be immediately operative in situations where the convergence would become dominant as in the so-called 'fogging' system of subjective or objective refraction where strong convex lenses are applied at the beginning of the process.

The accommodative convergence values found in this experiment show that 8–14 prism diopters may be considered as the usual and therefore optimum range, thus agreeing very well with Sheard's determination.[15] It is also further apparent that convergent accommodation of over 2 diopters is not common, no such case being found during the present investigation. The relatively great number of *S*s with 1.50 diopters, however, suggests that this amount represents the optimum value for this reflex. That the amount of convergent accommodation is not dependent upon the amplitude of accommodation of the individual is quite apparent when the values in the 4 age-groups are considered. The average amplitude of accommodation in the pre-presbyopic group, in which the amplitude is decreasing rapidly, must be much less than in any of the other groups, but an inspection of the age-group results will show that there are proportionally as many in the upper classifications in the older as in the younger *S*s. This optimum value of 1.50 diopters for the convergent accommodation confirms quite fully the results of Bestor who found, as the result of a survey of 139 cases, 1.50 diopters as the average amount of accommodative lag with fixation at 1/3 m.[16] Although not so designated or considered by Bestor, the difference between the accommodative lag and the total near point refractive value of 3 diopters must have been due to the presence of that amount of convergent accommodation.

The existence of a reflex relationship between accommodation and convergence, reciprocal in nature, in which either can be the primary source of the stimulus and the other the response, may be tentatively established as a result of the work reported in this paper. The development of physiological optics in general and visual psychology in particular will probably demand further investigations along these lines.

Summary

(1) Accommodation apparently due to a stimulus primarily derived from convergence was present in practically all of the *S*s and must therefore be considered as a normal reflex.

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[15] Sheard, *Op. cit., Amer. J. Physiol. Opt.*, 1, 1920, 249.

[16] H. M. Bestor, The interpretation of dynamic skiametric findings, *Amer. J. Physiol. Opt.*, 1, 1920, 229.

(2) The amount of convergent accommodation varied from 0–2 diopters with 1.50 diopters as the probable optimum value.

(3) The accommodative convergence values are in close agreement with those found in previous experiments.

(4) The amount of convergent accommodation in the average *S* is normally quite proportional to the amount of accommodative convergence, when measured by the methods used herein, as is shown by the relatively high positive correlation between them.

(5) The view is here suggested that there is a reflex relationship between accommodation and convergence, reciprocal and associative in nature, in which either can be conceived as the primary stimulus and the other the response.